The Closing Gap Between Dimensional and Surface Metrology

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International Dimensional Workshop 2000

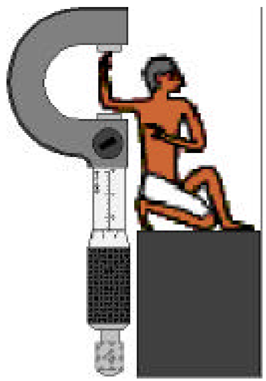
Digital
Metrology
Solutions

The Closing Gap

- Instrumentation Origins
- Instrument Overlaps
- Industrial Optimizations
- Information Overload
- Improvement Opportunities

Instrumentation Origins

- "Task Specific" measurement
  - Royalty's body parts (Cubit, span, etc.)
  - Physical Length Standard / Ruler
  - Caliper
  - Micrometer
  - Roughness Instrument
  - Form Measuring Devices
  - Coordinate Measuring Machine



Instrumentation Origins

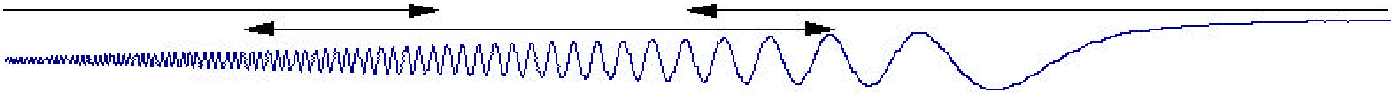
- Historically, instruments were generally developed based on a specific need.
  - e.g. “Large-Scale Length”
- More recently, instruments have become more “general purpose”.
  - e.g. “size”, “orientation, “form” over a range of scales.

Instrumentation Origins

Summary

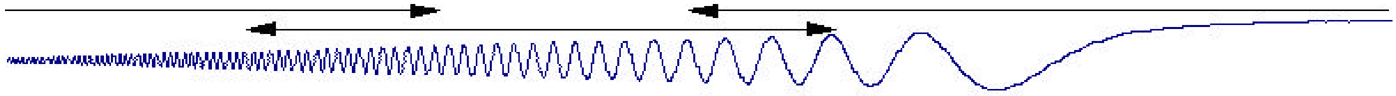
- Historically, instruments have been developed based on “the technological needs of the time”.

Instrument Overlaps

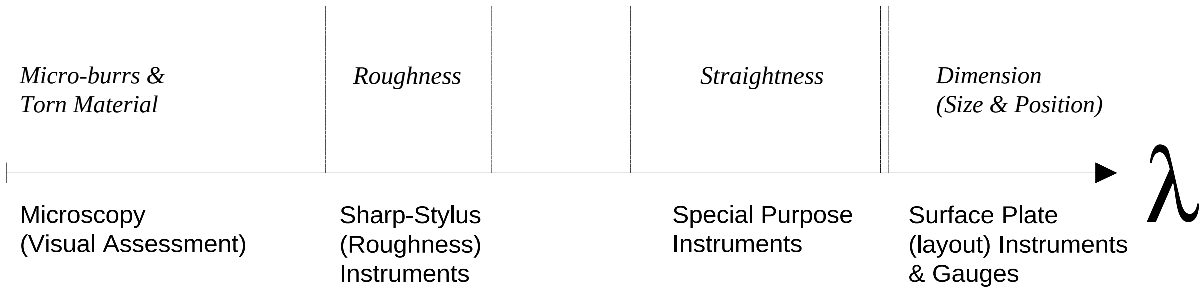


- The capabilities of these “general purpose” instruments have continued to evolve.
  - Improved accuracies
  - Improved data densities
  - Increased feature sets
  - Incorporation of alternative sensing mechanisms.

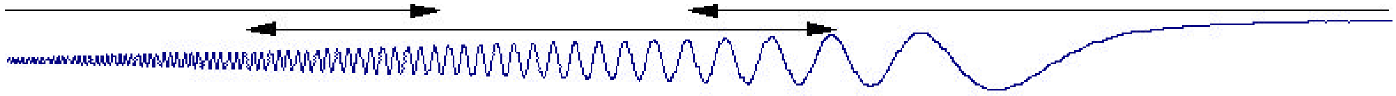
Instrument Overlaps



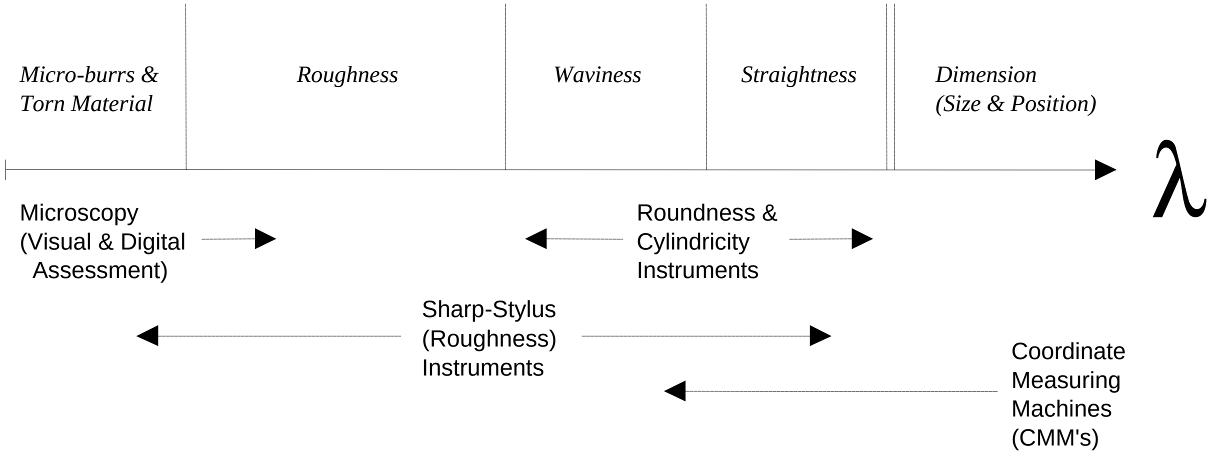
- Historical instrument bandwidth “boundaries”



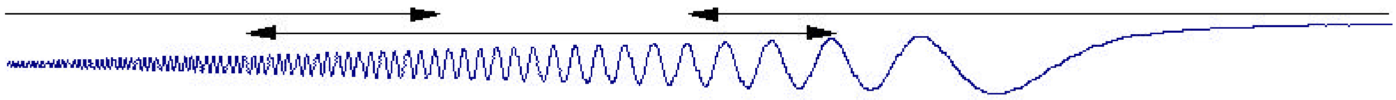
Instrument Overlaps



- Current trends in instrument bandwidth "boundaries"

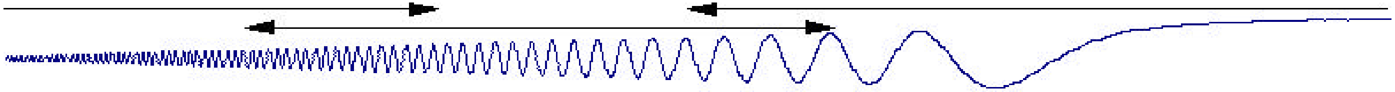


Instrument Overlaps

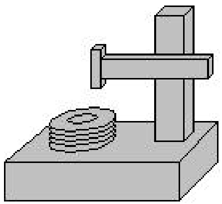


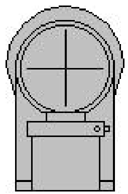
- There are many methods at the metrologist's disposal for any given measurement.
  - Which one is best?
  - Which one is available?
  - Which one is cheapest?
  - Which one is fastest?

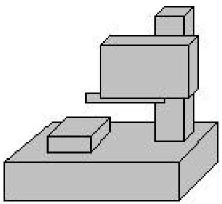
Instrument Overlaps



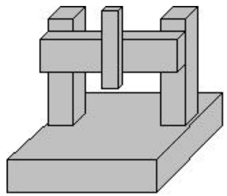
- Are different measurement approaches yielding the same results?
  - Example: Straightness







—	0.010



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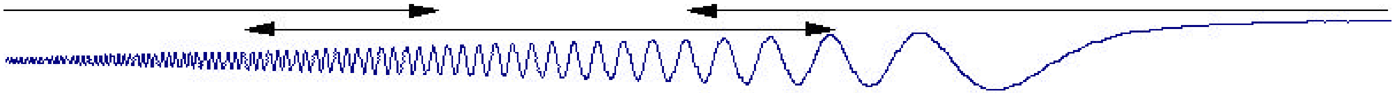
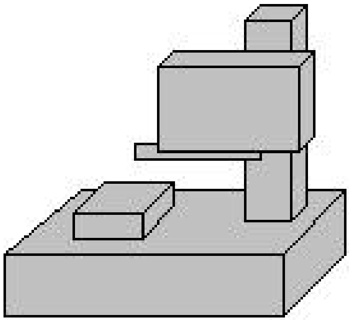
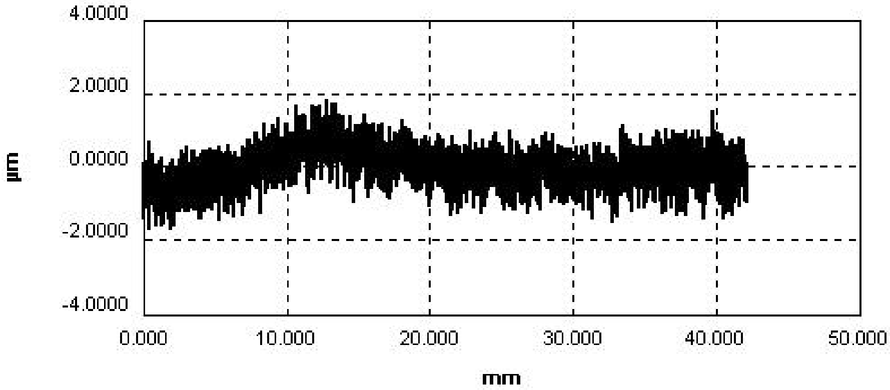


- Who is right?

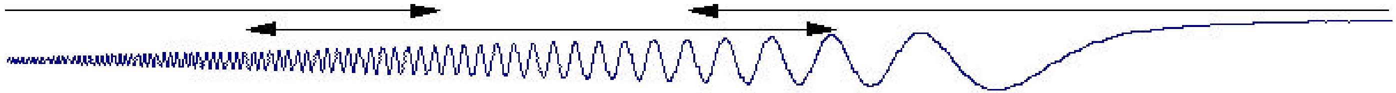
—	0.010

→ 3.46 µm





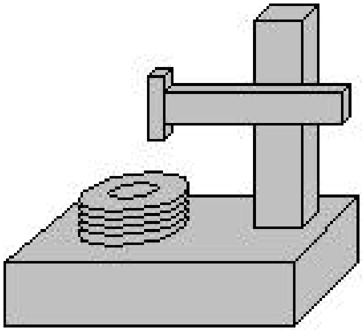
Instrument Overlaps

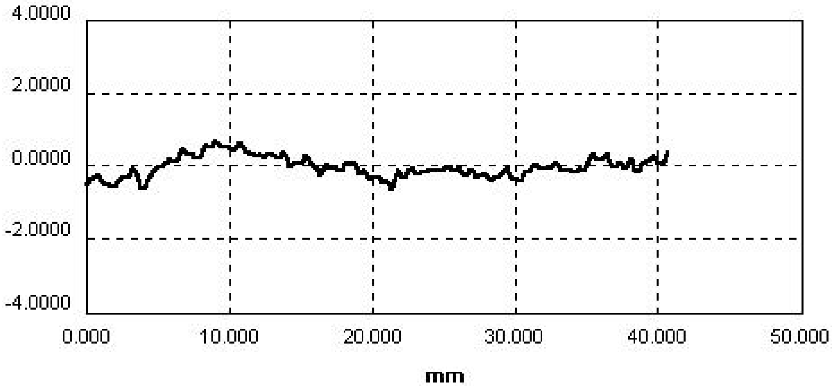


- Who is right?

—	0.010

→ 1.50 µm





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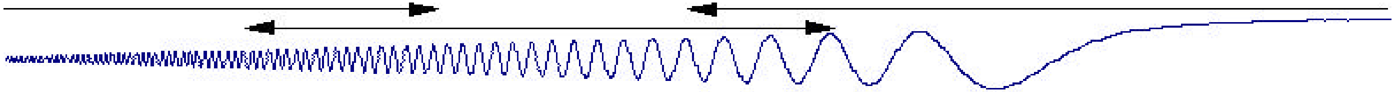
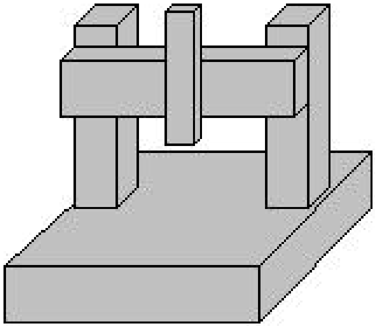
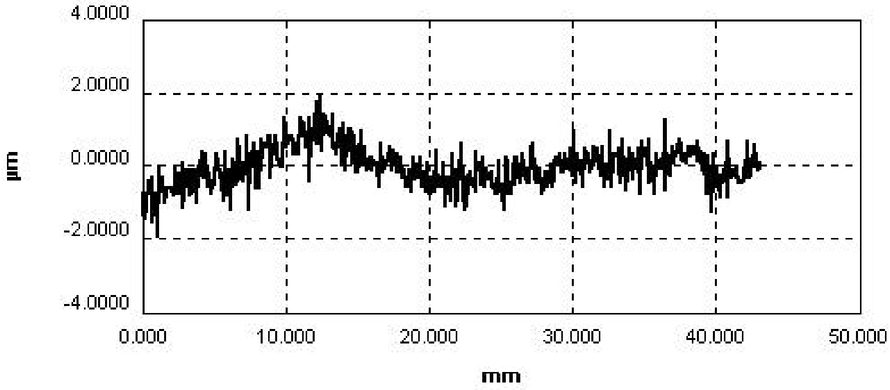


- Who is right?

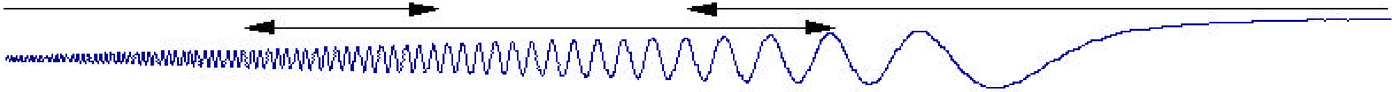
—	0.010

→ 1.96 µm





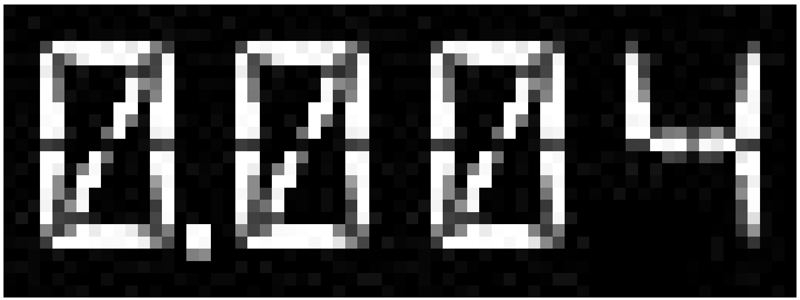
Instrument Overlaps



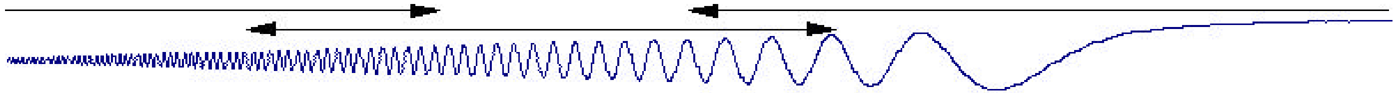
- Who is right?

—	0.010

→ 4.0 µm

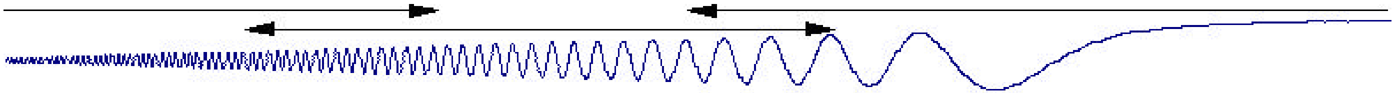


Instrument Overlaps

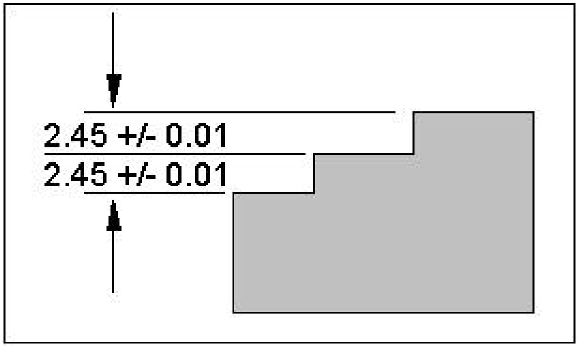


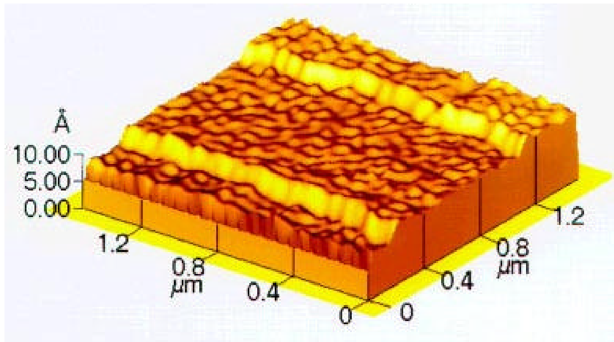
- Instrument design does not dictate application.
  - CMM's being used for scanning.
    - For example, roundness.
  - Scanning instruments being used for dimensional measurement.
    - For example, diameter.

Instrument Overlaps

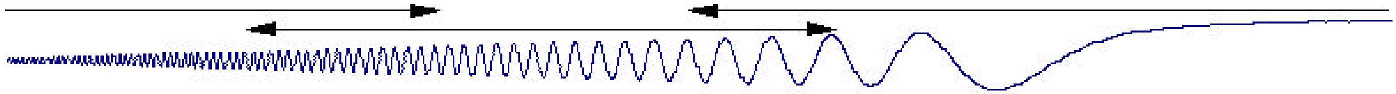


- Step heights over a variety of scales.
  - Height Stand?
  - CMM?
  - AFM?





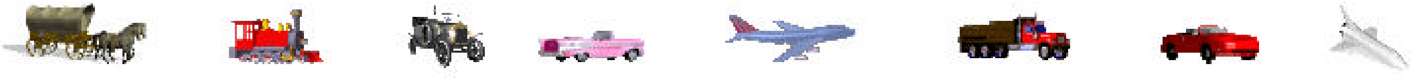
Instrument Overlaps



Summary:

- More recently, we have seen a dramatic increase in the push for “general purpose metrology”.
  - Driven by customers and suppliers.
- This has resulted in a significant “overlap” between technologies.

Industrial Optimizations



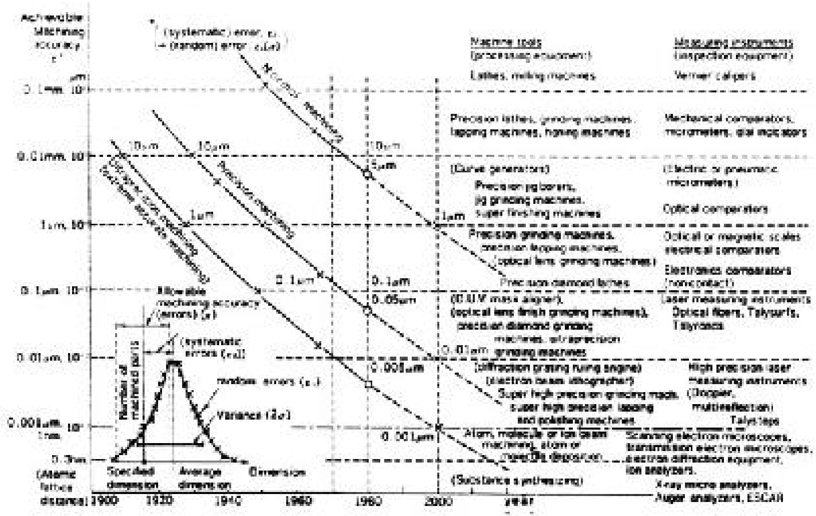
- Metrology has been a key element in industrial progress.
- Technology “leapfrogging”
  - Industrial needs drive metrology development.
  - Metrology development facilitates further industrial improvements.

Industrial Optimizations

- Increased demands continue to be placed on product technology.
  - Performance, safety, reliability, efficiency, cosmetics, comfort/ergonomics, etc.
- These increased demands on product technology trigger a subsequent demand on the metrology community.

Industrial Optimizations

- Shrinking Tolerances



Current status in, and future trends of, ultraprecision machining and ultrafine materials processing
by Norio Taniguchi, Tokyo Science University. Annals of the CIRP Vol. 32/2/1983 page 573

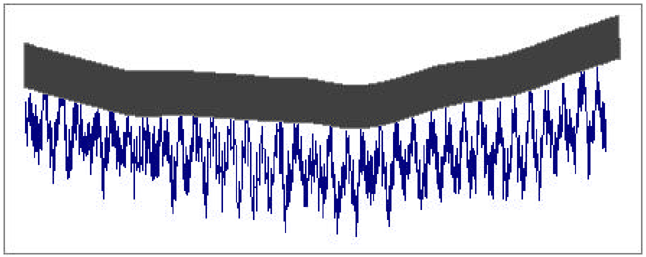
Tanaguchi 1983; Swyt 1995

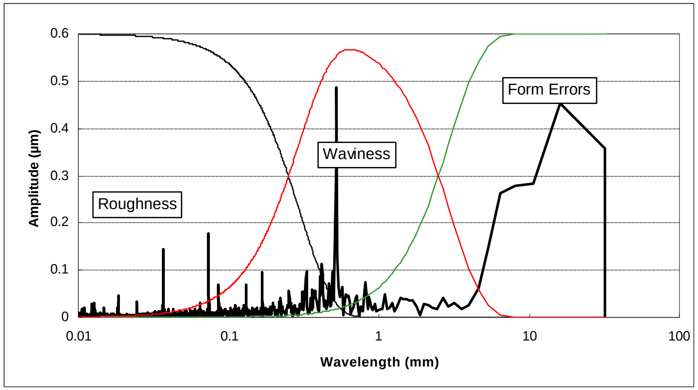
Industrial Optimizations

- Tolerancing strategies have become “scale-insensitive”.
  - Micron-level dimensional tolerancing
    - Profiles, sizes, positions, orientations, etc.
    - Problem: Separating “roughness” from “geometry” and “dimension”.
  - Large scale wavelength content.
    - “Harmonic” content, rates of change, etc.

Industrial Optimizations

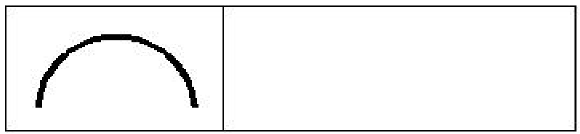
- Some tolerancing strategies have become “wavelength specific”.
  - Conformable interfaces
    - Sealing Applications





Industrial Optimizations

- Where do profile tolerances fit in?
  - The concept of “dimension” is often a “supporting” requirement.
  - “Scanning” and “wavelength control” are important considerations.
  - Examples of complex geometries:
    - Airfoils
    - Cam Lobes
    - Gear Teeth



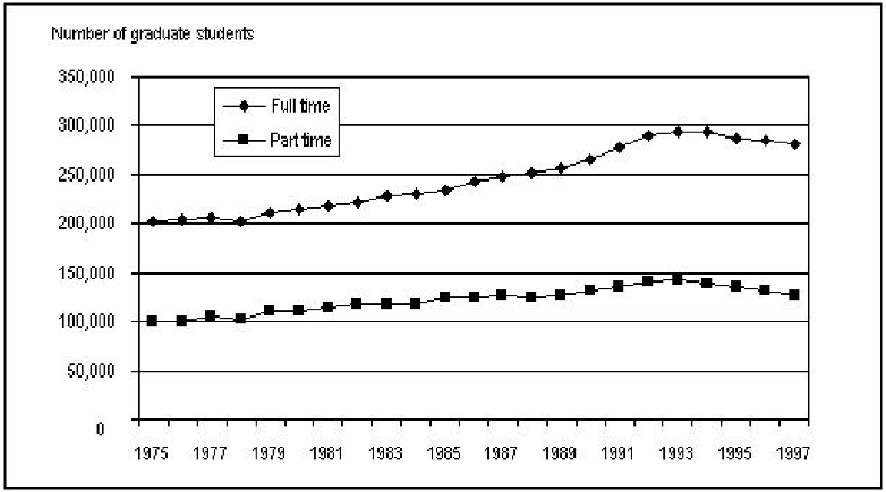
Industrial Optimizations

- Increased demand for engineers
  - "During the 1996-2006 period, employment in Science and Engineering occupations is expected to increase… by about 44 percent.
  - More than three times the rate for all occupations.

NSF "Science and Engineering Indicators – 1998"

Industrial Optimizations

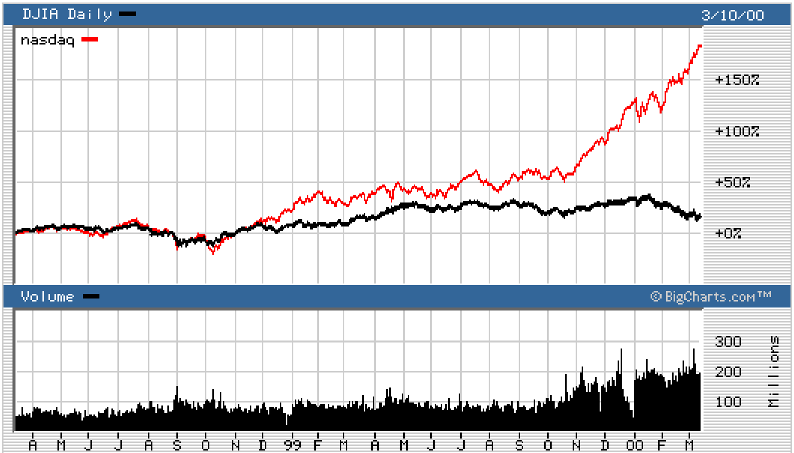
- The Decreasing Number of Graduate Engineers



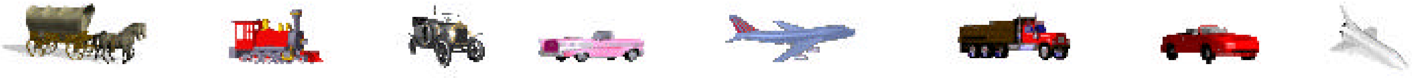
NSF/Division of Science Resources

Industrial Optimizations

- Many of the traditional customers of dimensional metrology are struggling to compete in the “internet economy”.



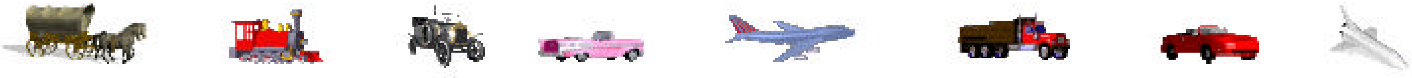
Industrial Optimizations



- These economic trends are driving tighter financial controls.
- “Non-Value Added”* activities (such as measurement) are being heavily scrutinized.

** Don’t shoot the messenger! I’m only repeating that which I’ve heard!!!*

Industrial Optimizations



Summary:

- Metrology providers and customers are facing many challenges. Including:
  – Delivery/Response
  – Technology
  – Staffing
  – Economic

Information Overload

01010001101101011110101010101100110110110000101010101101010110101010101101011
010101011110001001001010101011110101010010110101010110100010010010101010111

"The phenomenon of information overload is in its infancy. If according to some estimates, the amount of information doubles every eighteen months, then by 2015 there will be 1,000 bits of data for every fact in existence.

Information Overload

"But we will not necessarily be better informed. Meaningful facts – those that have reliable and relevant information – will become our most valuable resource."

- Richard Worzel

Flying with Fast Company

American Way – February 1, 2000

Information Overload

010100011011010111101010101011001101101100001010101011010101101010101101011
0101010111100010010010101010111101010100101101010101101000100100101010111

- Metrology is at the first step in the flow of “information”.
- Contrary to the beliefs of many metrologists…

We metrologists are a means to an end.

Information Overload

01010001101101011110101010101100110110110000101010101101010110101010101101011
010101011110001001001010101011110101010010110101010110100010010010101010111

- With today's computerized equipment, it has become too easy to generate enormous amounts of data.
- The question is:

"How much of this *data* is relevant *information*?"

Information Overload

01010001101101011110101010101100110110110000101010101101010110101010110101011
010101011110001001001010101011110101010010110101010110100010010010101010111

- Today’s metrology technology can produce information overload.
  - – CMM example: The size of a bore

	Tolerance Ref	Nominal	++Up/Lo Tol	Actual	Dev/Error	mm
** 50mm hole. **						
4	N0010 Diameter	50.000	0.550	50.519	0.519	-----***---
			0.450			
4	N0011 Position	50.630	0.157	50.648	0.066	xy ***---
		48.830	0.020	48.802		MMC: 4, 4

Information Overload

01010001101101011110101010101100110110110000101010101101010110101010101101011
010101011110001001001010101011110101010010110101010110100010010010101010111

- Today's metrology technology can produce information overload.
  - Surface Metrology Example: Roughness

Filter - M1 (Gaussian 50%): 0.0025 - 0.800 mm

Slp.	0.0000	°	Ra	0.406	µm	RTwi	47.1	%
Pt	11.114	µm	Rq	0.643	µm	Vc (-3.0)	14	#
Pp	1.914	µm	Rsk	-3.105		Rpq	0.371	µm
Pv	9.200	µm	Rku	22.105		Rvq	1.745	µm
Pa	0.424	µm	Rt	10.801	µm	Rmq	89.3	%
Wt	1.065	µm	Rp	1.916	µm	Rk	0.963	µm
Wp	0.363	µm	Rv	8.885	µm	Rpk	0.367	µm
Wv	0.702	µm	Rz	4.379	µm	Rvk	1.369	µm
Wa	0.152	µm	Rpm	1.212	µm	Mr1	8.7	%
			Rvm	3.167	µm	Mr2	84.3	%

Information Overload

Summary:

- We are providers of information.
  - Not just data.
- It is too easy to produce enormous amounts of irrelevant data.
  - Relevance is in the eyes of the customer.

Improvement Opportunities

This is the tough part!

Improvement Opportunities

- Continue to develop *"customizable"* metrology technology.
  - Purchasing advantages.
    - General purpose base hardware.
  - Personnel advantages.
    - Task-specific configuration (ease of use).
  - Technology advantages.
    - Customization to fit technology needs.

Improvement Opportunities

- Train, Educate, Teach, Instruct, Mentor, Tutor, Coach, School, Inform, Guide
  - Today's engineering community is becoming more *aware* of metrology, but very few *understand* metrology.
  - Metrology doesn't sell and apply itself. It requires educated customers.

Improvement Opportunities

- Strive to provide “information” rather than just “data”.
- Consider the questions behind the measurement:
  – Is this part in tolerance?
  – How well with this part perform?
  – What do I need to change in the process?

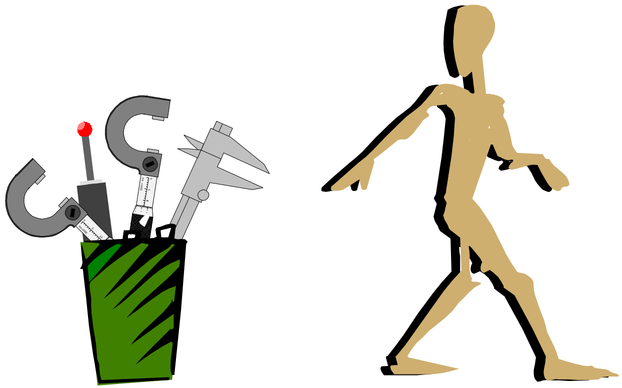
Improvement Opportunities

- The questions behind the measurement
  - Functional simulation
    - Finite elements
    - Fluid mechanics
    - Tribology
  - Process control
    - Graphical presentations
    - Data output / controller interaction
    - Artificial Intelligence based diagnostics

Improvement Opportunities

- Continue to emphasize the importance of measurement uncertainty.
  - Common statement in industry:

"My parts can't be bad –
it must be the gage."



Improvement Opportunities

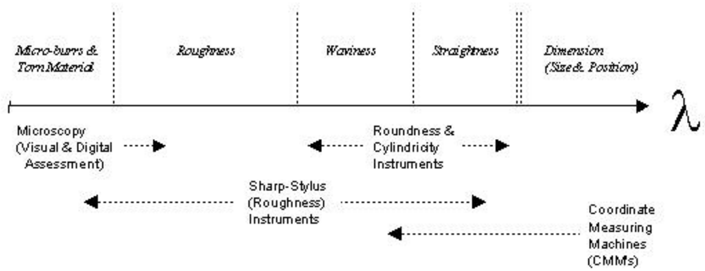
- *Uncertainty* doesn't necessarily mean that you are wrong.

It means that you are smart enough

to know your limits!!!

Improvement Opportunities

- A common language for specification and metrology independent of the type of measurement.
  - Addressing the overlap in measurement technologies.



Finally…

- We need to continue to interact (openly) in forums such as this!
  - We must recognize a balance between competition and collaboration.
    - Competition brings advancement and innovation.
    - Collaboration benefits the field of metrology (and customers thereof) as a whole.